Electricity

the

Burden Bearer

July

Edison's Laboratory and First Central Station (See page 13)

A winter scene at Menlo Park, N. J., early in 1881.

Electricity the Burden Bearer

By

William E. Keily

Assoc. A. I. E. E. M. W. S. E.
Class B Member N. E. L. A.
Member A. A. A. S.

Chicago
Illinois Committee on Public Utility Information
1920

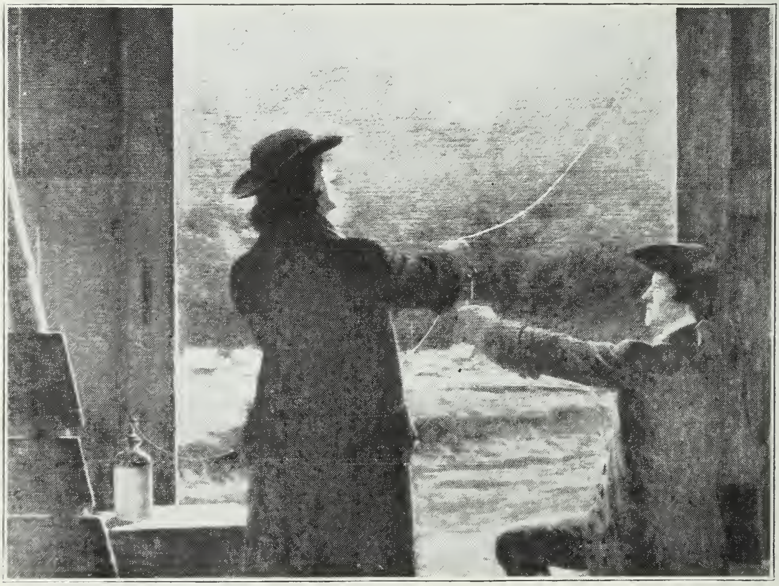
ELECTRICITY THE BURDEN BEARER

IT WAS only during the nineteenth century that electricity was really put to work, and, indeed, only in the last quarter of the last century that it was put hard at work. The word "electricity" itself was not coined until the middle of the seventeenth century. But magnets, first observed as natural magnets, or lodestones, had been known from antiquity; and magnetism (although the word was not then invented) was put to work in the twelfth century in Europe—perhaps earlier by the Chinese—the mariner's compass making possible, three hundred years later, the discovery of the New World by Columbus. Magnetic and electrical phenomena are closely allied, but the exact study of their relationships is only one hundred years old.

Sir Isaac Newton, that bright ornament of British science, compared himself to a boy playing on the seashore, diverting himself now and then in finding a pebble or shell smoother and prettier than ordinary, while the great ocean of truth lay all undiscovered before him. The modesty of true greatness!

With this distinguished example, we may devise a little allegory. We may suppose that at the time this boy was busy with his pebbles, say early in the eighteenth century, a curious jar lay partly embedded on the beach of the Ocean of Knowledge. It had been there for all the ages and had recently become known as Electricity. All the boys, including Isaac, had examined it with interest, but the leader wandered off to such toys as the Ether, Gravitation, Optics and Mathematics. But the jar, while not indeed "the only pebble on the beach," was the source of strange sights and sounds, and, as the years went by, other boys, in constantly increasing number, pressed around it, eager to discover its secret. For a long time a mist or smoke had

been observed to come from the mouth of the jar, and as the strange object was rubbed and pushed and kicked and sounded by lads from many lands (for all nations border on the Ocean of Knowledge, and here is truly freedom of the seas) the mist gradually assumed form. Not suddenly, as in the Arabian tale, but gradually, the smoke took the form of the Genius of Elec-



Franklin's Kite Experiment of 1752

The picture shows Benjamin Franklin demonstrating, with the help of his son, that lightning is an electrical phenomenon.

tricity—a giant indeed. Now hugely delighted, the boys, grandsons of the grandsons of other inquisitive boys, danced about and commanded this prodigy to do their bidding. And, because they, succeeding their forbears, had earned the right, by long-continued and increasingly intelligent effort, to direct the Force they had released, Electricity obeyed. At first the new servant was employed to carry messages, but later he was put at other work, until now he is fast becoming the dextrous agent by which power is applied to carry all the burdens of the world.

Such a comparative newcomer is this Electricity-at-Work that we often ask "What is electricity?" We might as well ask, "What is light?" or "What is heat?" or "What is gravity?" Are we sure that we can answer these questions? Electricity is a form of energy which has become a commonplace of our everyday surroundings but as of yesterday. The power that makes an apple fall in an orchard is really as mysterious as the power that causes the turning of the armature of an electric motor. But the boys around the old jar—all honor to them!—are still at their delightful work of investigating and speculating. Many of them have an idea nowadays, expressed in the so-called electron theory, that the atoms of all bodies are composed of still more minute particles which are negative corpuscles or charges of electricity associated, in the atom, with a positively electrified nucleus. Thus it has been conjectured that the whole universe is one vast electrical organism. But the electron theory is very complex, and not altogether susceptible of demonstration, and the truth is that no man can answer the question "What is electricity?" with any degree of certainty. But we can say something about what is done by means of electricity, and an attempt to do this, very briefly and with particular reference to the United States, is made in this pamphlet.

Pathfinders of Electrical Science

Fascinating as the story is, only the briefest reference can be made to the "high spots" of the history of electricity. Dr. William Gilbert, an English physician of Queen Elizabeth's time, is usually considered the founder of electrical science, although the "science" was very nebulous indeed for a century and a half after 1600, the year when Gilbert's great book, *De Magnete*. was published. Following him came a long line of experimenters in many nations, including Robert Boyle, Otto von Guericke, Stephen Gray and our own Benjamin Franklin, who demonstrated by his famous kite experiment in 1752 that lightning is an electrical phenomenon.

Galvani is given the credit of being the first man to detect a current of electricity. Hitherto the only electricity known had

been developed by friction. The date of Galvani's discovery was some time between 1786 and 1790. Volta, another Italian scientist, developed the first electric battery in 1800, and now the century which was to witness the great practical use of electricity was at hand. Sir Humphry Davy discovered the arc light and, using voltaic batteries, exhibited it on a grand scale before the Royal Institution of London in 1809. But it was seventy years after that before electric lighting came into general use, principally because there was no cheap way of producing electricity.

H. C. Oersted of Copenhagen announced the discovery of the magnetic effect of the electric current in 1820, and this was an important discovery because it opened the doors for the later development of electrical machinery, based on the great work of Michael Faraday of England, Davy's pupil, who discovered in 1831 the basic principles on which dynamo-electric machines are designed. He also announced the principle of induction, on which the modern transformer is based. About this time Joseph Henry, the famous American physicist, was also conducting his valuable experiments with electromagnets and induced currents. Many other scholars and inventors made important contributions to the science of electricity in the early part of the last century. Among them were C. A. Coulomb, G. S. Ohm, K. F. Gauss, W. E. Weber, A. M. Ampere, A. C. Becquerel and others. Later the torch of electrical science passed to other worthy hands, including those of such men as J. P. Joule, Clerk Maxwell, Lord Kelvin, H. A. Rowland, H. Hertz, C. P. Steinmetz and many others.

"What Hath God Wrought?"

The principles elucidated by the scientists have received practical application at the hands of a host of inventors (although it is impossible to make a sharp line of demarcation between scientists and inventors). The telegraph was the first great electrical invention, although the humbler art of electroplating was practically contemporaneous with it. Like nearly all inventions, the telegraph resulted from the work of many men, like

Henry in the United States, Cooke and Wheatstone in England and Gauss and Weber in Germany. But Americans give the credit for the invention of a practicable working telegraph to S. F. B. Morse, who began his experiments in 1832, exhibited a recording telegraph instrument in 1837 and sent the historic message, "What hath God wrought?" between Washington and Baltimore in 1844. At this time voltaic batteries were the only available source of electricity, and so, until well along in the seventies, the telegraph and electroplating were the only electrical applications in general use. To a considerable extent men like Edison who obtained their first practical electrical training in telegraphy were the pioneers in later electrical advancement. In 1858 the first messages were sent under the Atlantic by submarine cable. This cable became inoperative, but finally in 1866 a new cable was laid, and since that time many cables have been laid in the Atlantic, Pacific and Indian Oceans, connecting all the populous parts of the globe.

Enter the Dynamo and the Motor

The invention of the dynamo-electric machine, by which the mechanical energy of a steam engine, waterwheel, etc., may be converted into electrical energy, was the forerunner of the tremendous electrical development of the last quarter of the nineteenth century because it furnished cheap electricity. Many men had a hand in the invention of the dynamo. Pixii, Pacinotti, the Siemens brothers (William and Werner), Wilde, Gramme, Brush, Edison, Hopkinson, Elihu Thomson, Edward Weston and William Stanley may be mentioned, although other inventors made important contributions to the art. Dynamos, in something resembling their modern form, made their appearance between 1867 and 1873. They gave a great impetus to the study of the possibilities of electric lighting, a subject that had been talked about ever since Davy's historic experiment. In fact, electric-lighting experiments had been constantly going on in various countries. Sir W. R. Grove of England recorded reading by an incandescent platinum spiral as early as 1840, and in 1859, Moses G. Farmer, a Yankee inventive genius who was

about a quarter of a century ahead of his time, lighted his house in Salem, Mass., by crude incandescent lamps, using platinum wire as the light-giving body.

The modern electric motor is said to date from 1873, when it was found, at the Vienna Industrial Exhibition of that year, that a Gramme dynamo could be reversed in operation and made to serve as a motor. The first storage battery of importance was made by Gaston Planté in 1860, but a very important development was that of Camille A. Faure in 1880. Brush and Edison of the United States have made many improvements in the storage battery. The first electric boat was devised and operated by Jacobi on the River Neva at Petrograd in 1839. The ingenius but crude electric motor employed was operated by electrical energy from primary batteries, and the boat, which was operated at a speed of three miles an hour, was mainly interesting as an experiment. It was fifty years later, following the invention of the storage battery and of a practicable electric motor, before electric launches came into use. The submarine torpedo boat, which is, when submerged, an electric boat, is the result of the work of many experimenters, including Lake and Holland in the United States. The *Zédé* of the French Navy was built in 1893.

Rise and Decline of Arc Lighting

In the United States the practical electrical development of the latter part of the last century followed three main lines. As might perhaps be expected, arc lighting was the first of these. The Jablochkoff candles, which were arc lamps of a peculiar design, created a sensation in Paris and London in 1878. But before that, the American, Charles F. Brush, had turned his attention to arc lighting. He completed drawings for a dynamo of his own design in 1876, and two of these machines were exhibited at Franklin Institute in Philadelphia in 1877. In this year also Brush exhibited a new arc lamp. The first Brush arc lighting dynamo and lamp actually sold were shipped to Cincinnati in January, 1878. In this year arc lights (Brush) were exhibited in Chicago for the first time. Elihu Thomson built an arc-

lighting dynamo in 1879, which was used in Philadelphia in that year. Edward Weston, James J. Wood and Charles E. Scribner were also early designers in this field.

Dr. Brush continued to improve his lighting system, and finally dynamos capable of operating 125 arc lamps made their appearance. By the end of 1880 about 6,000 arc lamps had been installed in the United States. Much trouble was experienced in the early days with the carbon rods used in the arc lamps, but all these difficulties were overcome. The first carbons for arc lamps were sold at the rate of $240 a thousand, but in later years they came down to about $10 a thousand. In the heyday of "series" arc lighting, before the "enclosed arc" was introduced, the annual consumption of carbons reached nearly 200,000,000 in this country alone.

Street arc lighting was first effected in Cleveland in April, 1879. The Telegraph Supply Company of Cleveland changed its name to the Brush Electric Company in 1881, and about ten years later this company was merged into the Thomson-Houston Electric Company. Due to the remarkable increase in the efficiency of the incandescent lamp and its greater convenience in operation, arc lighting has suffered a great decline in recent years. It is probably true, however, that the early success of arc lighting promoted and hastened the development of incandescent lighting as well as power transmission and electric railways.

Edison the Inventor of the Modern Central Station

But to Thomas A. Edison clearly belongs the credit of creating the modern electric central-station system for light and power. Edison was already a distinguished inventor when, in 1878, backed by several men of means, he turned his attention to electric lighting. The original Edison Electric Light Company of New York, the parent company, was organized on October 16, 1878. From the first, Edison conceived an electric-lighting system, not only an incandescent lamp and an electric generator to supply the electricity, but also, and perhaps most important, a system of wiring such that one lamp could be turned

out without affecting the burning of the others. He also devised switching mechanisms, an electricity meter and many other accessories. Not only that, but Edison and his assistants had to devise machinery and apparatus to make these various electrical devices. Everything had to be created out of thin air, as it were. This was the stupendous task accomplished by Edison.

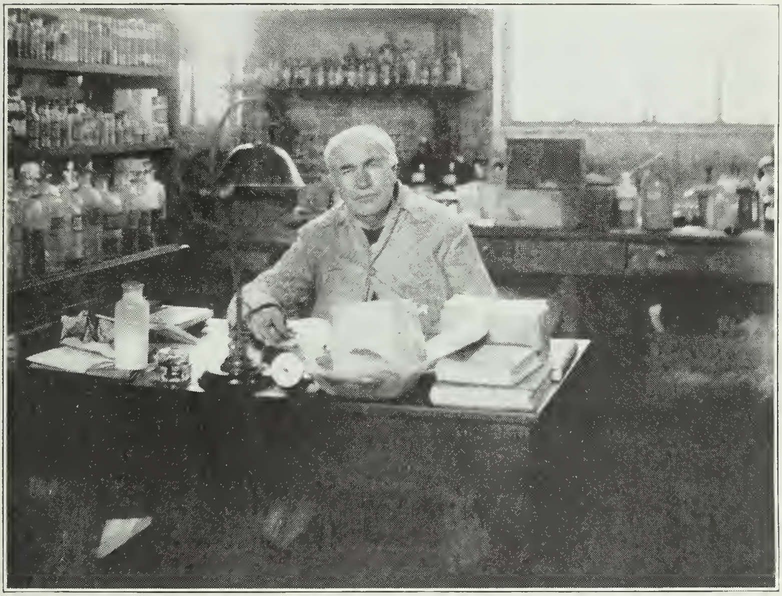
In experimenting for an incandescent lamp to be connected between the wires of an electric circuit, or "in parallel," instead of being "in series" with the other lamps on the circuit, as in the case of the early arc lamps, Edison at first used platinum wire for a filament and then tried mixing the platinum with iridium. There were many experiments before the carbon filament burning in a vacuum was hit upon. It was no doubt these experiments that were described before the American Electrical Society, of Chicago—the first and for several years the only national electrical society in the United States—by George H. Bliss on December 11, 1878. This was one of the very first descriptions of Edison's light. However, the successful incandescent electric lamp with a carbon filament was not produced by Edison until October 21, 1879. It was not until some time later that the Edison carbon incandescent lamps came to Chicago. Dr. H. S. Carhart, then professor of physics in Northwestern University, believed that he received from Edison, in May, 1881, the first incandescent lamps that ever came to Chicago.

Edison was not alone in trying to produce an incandescent electric lamp. Sawyer and Man took out their first patent for an incandescent electric lamp on June 18, 1878. Other early workers in this field were Joseph W. Swan of England and Hiram S. Maxim. But after some years of controversy and court litigation it was generally conceded, both in this country and abroad, that Edison was the first to produce a practically useful electric lamp on the incandescent principle with a filament of carbon in a vacuum.

At Menlo Park Early in 1881

In the winter of 1880-1881 Edison installed a central-station system at Menlo Park, New Jersey, for the purpose of demon-

strating the success of what was popularly called the subdivision of the electric light. The generating station was composed of nine or ten dynamos of a rating of perhaps six to ten kilowatts each, which may be compared with the 35,000-kilowatt or 50,000-kilowatt machines of the present day. Mr. Edison's workshops and laboratory and his own residence and those of his assistants were lighted by incandescent lamps. The wires were laid under-



Thomas A. Edison, at Seventy-Three, Still Hard at Work

ground. There were motors at work in the laboratory, and, in fact, all of the essential features of modern central-station generation and distribution were shown.

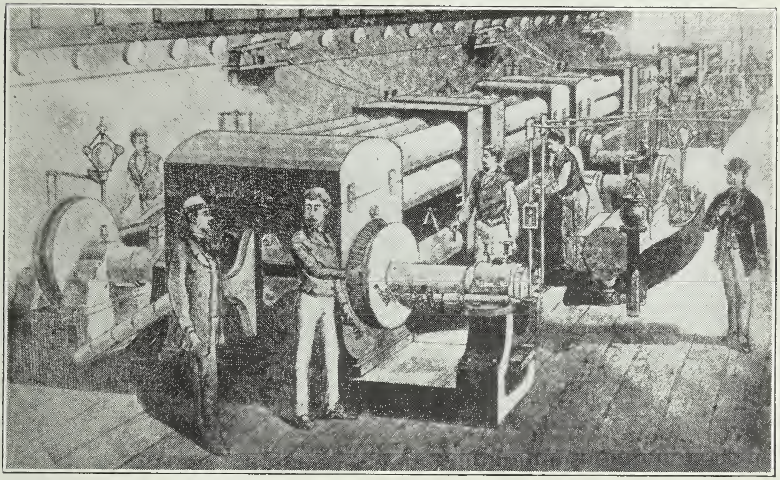
Many years later, Samuel Insull wrote an account of this first central station. "It was on the evening of the first of March, 1881," he said, "that I paid my first visit to Menlo Park. I had arrived in New York from England the day before, having come on the invitation of Mr. Edison to act as his private secretary. We had heard all kinds of gossip in London about

the wonderful things that were being done at Menlo Park in the way of practical electric-lighting work. Mr. Edison had been writing to his English friends for two years prior to the date of my arrival in New York, telling of his success, but as we had had no demonstration of it on the other side of the water, and the scientists on both sides of the Atlantic expressed their doubts as to the results of Mr. Edison's experimental work, my natural desire when I arrived was to pay an immediate visit to Menlo Park and cable my English friends that I had actually seen Mr. Edison's central-station system at work. So far as the service rendered, this first experimental plant at the birthplace of the central-station industry was as perfect as the service now given by any of the central-station companies in our large cities. * * * At the same time, and running from the same generating station, Mr. Edison had in operation about a mile of electric railway, the track being partially insulated and used for conducting the current. A speed of 42 miles an hour was attained, and over 5,000 people rode on this experimental electric railway."

The Idea Begins to Spread

The first commercial central-station system in the world that has been in operation continuously ever since was that of the Edison Electric Illuminating Company of New York, which was organized on December 17, 1880. This company began the work of laying the street mains for the Pearl Street central station in New York in July, 1881, and the plant was put into permanent operation on September 4, 1882. It is believed that the first commercial central station for incandescent electric lighting was one erected in London, England, in April, 1882. However, this plant was discontinued two or three years later. The Pearl Street station in New York, on the other hand, was the original generating station of the present system of the New York Edison Company. The Western Edison Light Company of Chicago was chartered on May 25, 1882. It sold the machinery for a small waterpower-driven central station which was put into operation in Appleton, Wis., on or about October 15, 1882. This was the second Edison central-station system in the United States.

Edison's three-wire system of wiring, which effected a great saving in copper, was developed in 1882 and 1883. The central-station idea grew rather slowly at first, owing to the amount of capital required, although many isolated electric-light plants were installed. But in a few years Edison electric central stations were established in all the larger cities. That in Boston



Dynamo Room of the Old Pearl Street Edison Central Station in New York City, Built in 1882

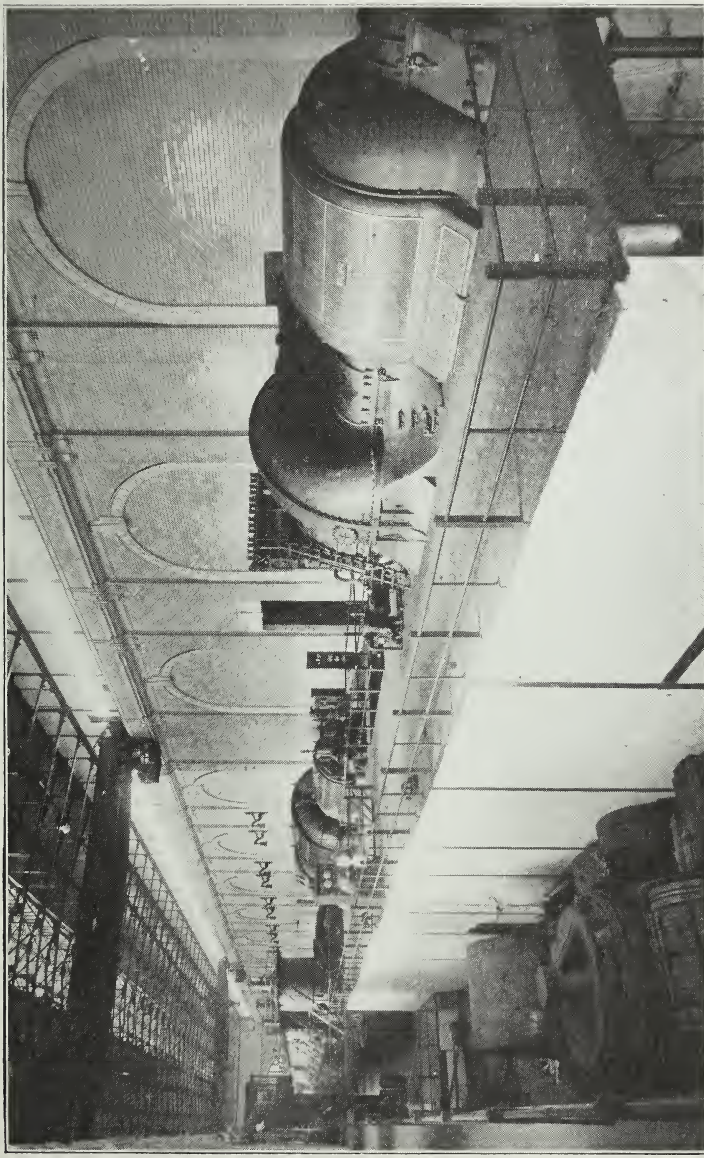
began business in 1886. In 1887 The Chicago Edison Company succeeded the Western Edison Light Company, and in 1888 it began to manufacture and distribute electricity.

From 1881 to 1892 the Edison manufacturing interests, coming into being as a group of new industries, expanded amazingly. The indomitable leader had as assistants a body of enthusiastic and loyal men who shared with him the honor of being Edison pioneers—men like Charles Batchelor, Samuel Insull, Edward H. Johnson, John Kruesi, Francis R. Upton and Sigmund Bergmann. With the help of these men and others of their kind, Mr. Edison built up the Electric Tube Company, Edison Machine Works, Edison Lamp Company and Bergmann & Company, all of which were merged into the Edison General Electric Company

in 1889. The Edison works at Schenectady, N. Y., were opened on Christmas Day in 1886. When the Edison General Electric Company was organized Mr. Insull was made second vice-president of the company, having charge of manufacturing and selling. In 1892 the Edison General Electric Company was consolidated with the Thomson-Houston Electric Company to form the present General Electric Company. Mr. Insull was elected second vice-president of the newly organized company, but he immediately resigned to become president of The Chicago Edison Company, predecessor of the present Commonwealth Edison Company, which has become the largest individual electricity-supply organization of the world under Mr. Insull's administration.

The Alternating-Current System

Meanwhile the third system for electricity supply was being developed in the United States. This was the alternating-current system, and with it is inseparably connected the name of George Westinghouse. Both the early arc-lighting and the early Edison systems, it may be explained, used direct current, perhaps following the lead of the voltaic batteries. Mr. Westinghouse, an American inventor and business man who established the great companies which bear his name, came into prominence as the inventor of mechanical devices for railroad use, such as air brakes, switches and signals. However, he also had the distinction of recognizing at an early date the merits of the alternating-current system of electrical distribution, and he gave much of his personal attention to the development of this system in its formative period. He purchased some electrical patents from William Stanley as far back as 1883. Two years later he purchased the patents of Gaulard and Gibbs for the distribution of electricity by means of alternating currents, and in 1886 he organized the Westinghouse Electric Company, which was succeeded by the Westinghouse Electric and Manufacturing Company in 1891. In 1885, at Great Barrington, Mass., William Stanley effected the first commercial distribution system using alternating currents. The first regularly operated alternating-



An Interior View in a Modern Electric Generating Station

This shows part of the turbo-generator room of Fisk Street Station, Chicago. It is 635 feet long and contains fourteen great units (horizontal and vertical) capable of an output of 230,000 kilowatts of electrical energy.

current plant in the United States was that established by the Westinghouse Company at Greensburg, Pa., in 1886. The alternating-current transformer, a most important piece of apparatus, based, as has been stated, on Faraday's discovery of induction, was crudely developed in England by Gaulard and Gibbs, but made a practical, working accomplishment by William Stanley.

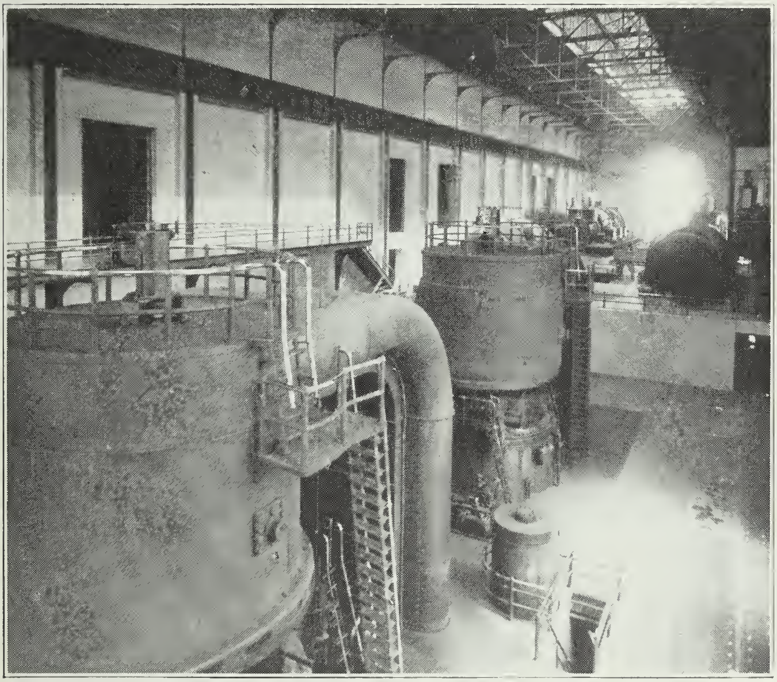
The introduction of the alternating-current system and the Edison three-wire system gave a tremendous impetus to the electric-lighting industry. Mr. Westinghouse pushed the alternating-current system to a commercial success. One of his triumphs was the incandescent lighting by alternating current of the World's Fair at Chicago in 1893, using a so-called "stopper" type of incandescent lamp necessitated by the patent situation at that time. This lamp, which was gas-filled, like some of the tungsten lamps of today, was considered by many as a doubtful substitute for the Edison lamp, but it worked nevertheless, and the World's Fair was very well lighted. But it was the Edison type of electric incandescent lamp which finally prevailed. In addition to being the head of a number of corporations in America, representing an investment of many millions of dollars, Mr. Westinghouse established large factories and works in Europe.

In the Days When Competition Was Bitter

In 1888 Nikola Tesla contributed very materially to the development of the alternating-current side of the electricity-supply utility. In that year his polyphase-current patents, which form the basis largely of the alternating-current generators and motors now in use, were taken out. Among the first to recognize the great importance of Mr. Tesla's motors were Mr. Westinghouse and his advisers. The Tesla patents were purchased by the Westinghouse Company and proved a very valuable asset. The famous Lauffen-Frankfort electrical power transmission in Germany, using the Tesla system, was accomplished in 1891, but it is believed that the first crude electric power transmission in practice dates from 1890, when the beginning was made in one of the mining regions of Colorado. The great hydro-electric development at Niagara Falls dates from 1895, although its main

electrical characteristics had been determined by an international engineering commission in 1893.

Electricity-at-Work has been directed not only by great scientists, inventors and engineers, but also by great men of affairs. Some of these have been mentioned. In 1882 Charles A.



A View in Northwest Generating Station, Chicago

Here machines of the vertical type are in the foreground. The rated capacity of this station is 165,000 kilowatts.

Coffin, who had been engaged in manufacturing, became interested, with others, in the inventions of Elihu Thomson and Edwin J. Houston of Philadelphia. Prof. Thomson and Prof. Houston had been teachers in the Central High School of Philadelphia, and had made some electrical inventions, principally relating to arc lighting, jointly. Dr. Thomson resigned his professorship in 1880 and boldly cast his lot with the then truly

infant electrical industry. Prof. Houston (who died in 1914) remained at the Central High School for many years afterward, but the joint name was long employed. The Thomson-Houston Electric Company established a small factory in New Britain, Conn. These works were taken over by Mr. Coffin and his friends, and in the latter part of 1883 were transferred to a new factory in Lynn, Mass. Here the Thomson-Houston Electric Company became one of the great electrical manufacturing enterprises of the country. It was merged into the General Electric Company in 1892. Elihu Thomson has been consulting engineer for the Thomson-Houston Electric Company and the General Electric Company for many years.

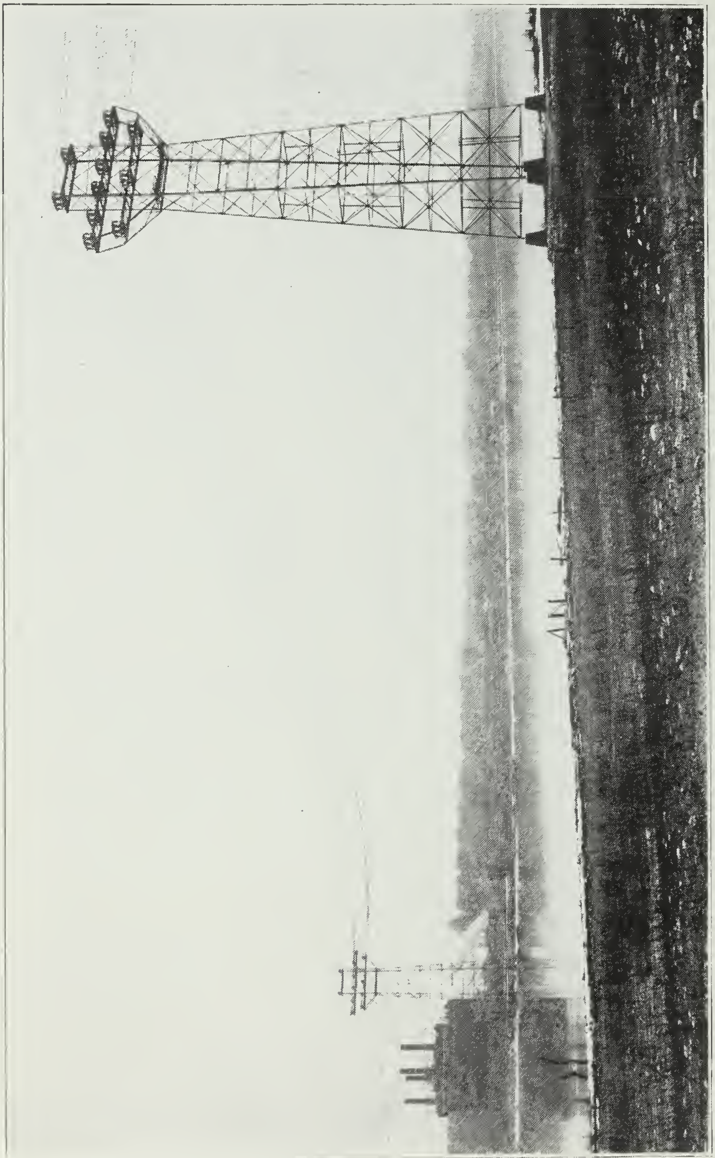
While the direct-current electricity business was being exploited by the Edison companies, the Westinghouse Electric Company and the Thomson-Houston Electric Company were engaged in pushing the alternating-current business and using as a basis for it the arc-lighting companies which in a number of cities had been formed mainly by the Brush Electric Company for doing city lighting. In 1885, when the National Electric Light Association was formed in Chicago, it was thought that there were perhaps eighty central station companies in the country, mainly arc-lighting companies operating at night only. For many years there was a most acrimonious discussion between the champions of the direct current and of the alternating current. Both in the end prevailed, for the old Edison central-station companies have always kept the lead in connection with central-station development, while actually the alternating-current system is now used so extensively in generating and transmitting electric power that no one would think of building a direct-current central station for use where any large amount of electrical energy is required over an extended area. But for some purposes, such as most electric-railway motors, charging storage batteries, etc., direct current is still required.

A Glance at the Telephone

In this pamphlet, devoted principally to the lighting and power developments of Electricity-at-Work, but scant attention

can be paid to that wonderful invention—the telephone. In 1854 Bourseul of Paris suggested an electric telephone, and in 1861 Philip Reis of Germany devised an electric telephone which would transmit musical tones. Daniel Drawbaugh of Pennsylvania alleged that he had made an electric telephone in 1867-1868. Elisha Gray and Thomas A. Edison were also early telephone inventors of the first importance. But the courts decided that Alexander Graham Bell invented the electric speaking telephone, his first application for a patent being on February 14, 1876. Blake and Berliner were also early telephone inventors. Bell telephone companies were established in all the large cities, with a long-distance system connecting them. When the fundamental Bell patents expired a large number of Independent competing companies sprang up in the nineties. A formidable telephone opposition was developed, and for a number of years there was bitter warfare between the two camps. At the present time a large majority of the Independent companies connect with the American Telephone and Telegraph Company, or its subsidiaries, for long-distance service. Strowger, an electrical engineer and mechanician of Chicago, introduced the first automatic telephone system in 1891. The earliest automatic designs were quite complicated, but constant improvements were made, and the equipment was simplified. The automatic system came into use gradually at first in Independent exchanges in small places and later in larger cities. According to present indications, the next great telephone development will be the use of automatic exchanges, both by Bell and Independent companies.

The Western Electric Company, Incorporated, has been closely identified with the telegraph and telephone industry in the United States, but it is also a large manufacturer of electrical supplies and appliances, and at one time made a complete line of electrical machinery and apparatus, both direct-current and alternating-current. It is the outgrowth of a telegraph-instrument shop established in Cleveland by the late Enos M. Barton in partnership with George W. Shawk, in 1869. Within a year Mr. Shawk sold out to Elisha Gray, later prominent as an electrical inventor, and who was president of the International Elec-



Modern Electric Transmission-Line Construction

A 1,000-foot span across the Des Plaines River south of Joliet, Ill., with generating station on farther shore. The towers are 175 feet high.

trical Congress at Chicago in 1893. The firm name was changed to Gray & Barton, and a little later Gen. Anson Stager, a telegraph pioneer, afterward vice-president of the Western Union Telegraph Company, became an equal partner in the firm on condition that the business should be removed to Chicago. This was done in 1870. The little shop began to do manufacturing, and in 1872 the Western Electric Manufacturing Company was incorporated to take over the business. Gen. Stager was the first president of the company. Mr. Barton was the secretary, and later became vice-president. In 1879 the company was reorganized as the Western Electric Company, Gen. Stager (who also became president of the Western Edison Light Company, previously mentioned, in 1882) remaining as president until his death in 1885. In 1886 Mr. Barton became president of the company, retiring in 1908 to become chairman of the board of directors. The Western Electric Company was reorganized as the Western Electric Company, Incorporated, in 1915.

Early Days of the "Broomstick Train"

The electric railway also came into being in the last quarter of the nineteenth century. The first miniature electric railway carrying passengers was put in operation at Berlin in 1879 by Siemens & Halske. Mention of Edison's work has already been made, but Edison dropped the electric railway for the electric light. In 1883 an electric railway car was operated at an exhibition in Chicago on the Lake Front in the old Exposition Building where the Art Institute now stands. However, the commercial introduction of the electric railway in the United States dates from the building of a complete and successful system in Richmond, Va., in 1887 and 1888, by Sprague. The first elevated electric railway in the United States was that at the Chicago World's Fair of 1893. Stephen D. Field, Charles J. Van Depoele, Leo Daft, Sidney H. Short and others were prominent electric-railway inventors, but it was Frank J. Sprague, sometimes called "the father of the electric railway," who, more than any other man, brought the thing to pass. Within six years from the opening of the Richmond system five-sixths of the

existing horse-car lines in the country had been converted into electric railways. Seldom has an industrial revolution been so quickly accomplished. The Van Depoele Electric Manufacturing Company of Chicago was absorbed by the Thomson-Houston Electric Company in 1888, and the Sprague Electric Railway and Motor Company by the Edison General Electric Company in 1890. The Westinghouse Company was also active in electric-railway work. Oliver Wendell Holmes, when he nicknamed the trolley car, with its upstanding pole, the "broomstick train," could hardly have foreseen that the time would come when it would carry 15,000,000,000 passengers a year in this country alone!

Electrical Pioneers Not Without Honor

Being a child of the nineteenth century, Electricity-at-Work could not be measured by units having names extending back into the dim past, like foot, pound and quart. It was necessary to invent designations for the electrical units of measurement, and it was decided, happily, to honor the names of electrical pioneers in this way. The units ohm, volt and ampere were first authoritatively defined in 1881, and the watt, more commonly used in "kilowatt," in 1889. They commemorate the names of a German, an Italian, a Frenchman and a Scotchman. Electrical units less frequently encountered in non-technical literature perpetuate the names of other electrical scientists, including Coulomb, Maxwell, Gauss, Gilbert, Faraday, Henry and Joule. The fundamental electrical units are international, and they are also, like the metric system, expressed in the decimal notation, a kilowatt being a thousand watts, and so on. The watt is the electrical unit of power, and the kilowatt-hour is the unit of work which is usually used in the sale of electrical energy.

The many and important applications of electrochemistry are all comparatively modern, although the electrical production of aluminum was described in patents granted in 1885. Electric welding, as extensively used in the present day, was invented by Elihu Thomson in 1886. The electric automobile, in its first crude form, appeared about 1890, although "electric carriages" were known before that date. In 1891 Branly invented the

coherer used in wireless telegraphy. Marconi greatly developed and improved "wireless" in 1895 and thereafter. X-rays were discovered by W. C. Roentgen in 1895.

Civilization's Servant at Work

Wonderful, indeed, have been the accomplishments of Electricity-at-Work since the lights of the first central station were reflected from the snows of Menlo Park early in 1881. It has brought light and cheer to the depressed, strength to the weak, and relief to the weary. It is found in the home, the office, the hospital, the laboratory, the workshop, the factory, the rolling-mill, the mine, the store, on the farm and the railroad—practically everywhere where heat, light and power are required. It is as efficacious in producing a soothing breeze at the bedside of a sick child as it is in towing 30,000-ton ships through the Panama Canal. In the fanciful language of H. A. Seymour:

This very subtle essence is the lightning of the gods;
'Twill travel instanteously forty million rods.
You turn it into light or heat or power, as you will;
Commercially it "takes the cake," no matter what the odds.
Its brilliant light can equal all the blaze of noonday sun;
'Twill heat a smelter furnace; it will bake your breakfast bun,
Or gently rock the baby's cradle, pull a train uphill,
Or do a thousand other stunts—the list is just begun.

Then ho! for amperes, watts and volts
And artificial thunderbolts!
For roaring fires, copper wires, central energy,
For engines singing day and night,
For motive power, heat and light,
For clean and ready, safe and steady Electricity!

Among the reasons why the electricity-supply utility in the United States has exhibited such a rapid development are the high efficiency of the electric generator, enabling mechanical energy to be changed into electrical energy with but small loss; the ability to transmit this energy over long distances at high efficiency by means of simple and relatively inexpensive construction; the great improvement in efficiency of the incandescent electric lamp; the development of the steam turbine, which in

the larger sizes effects a saving in steam of 50 per cent or more in comparison with the reciprocating steam engine, and the great economies effected by centralizing power generation in large units. The development of the transformer and of the rotary converter in alternating-current distribution also had much to do in spreading electricity.

Steam turbines have practically replaced reciprocating engines in large electric generating stations. In 1896 George Westinghouse secured the rights to manufacture the Parsons steam turbine in this country. Turbines came into use slowly at first, and it was not until 1903 that one central-station company manifested sufficient boldness to build an all-turbine generating station. This company was the Commonwealth Electric Company of Chicago, a predecessor of the Commonwealth Edison Company, Samuel Insull being its president and the man responsible for the innovation. The station referred to was the famous Fisk Street plant, and the original turbines were of the Curtis type made by the General Electric Company. So rapid was the progress of the art that within six years these original turbines were taken down to make way for others of a more efficient type. The original 5,000-kilowatt machine at Fisk Street was re-erected at the Schenectady works of the manufacturing company, where it now stands as a monument to the development of the art.

Power Transmission and Railroad Electrification

Electricity has made it practicable to transmit over long distances power generated at waterfalls or other economical source of supply. Some of the earliest hydro-electric systems were built in the Rocky Mountain and Pacific states, owing to the abundance of waterpower and the scarcity of coal in that part of the country. Electric power is now transmitted hundreds of miles at pressures of 150,000 volts or more. The Niagara Falls region, both on the American and Canadian sides, is still the greatest single center of hydro-electric development. In Illinois the largest electrically developed waterpower is that of the Sanitary District of Chicago, on the Chicago Drainage Canal, but this is comparatively small, being rated at about 28,000 kilo-

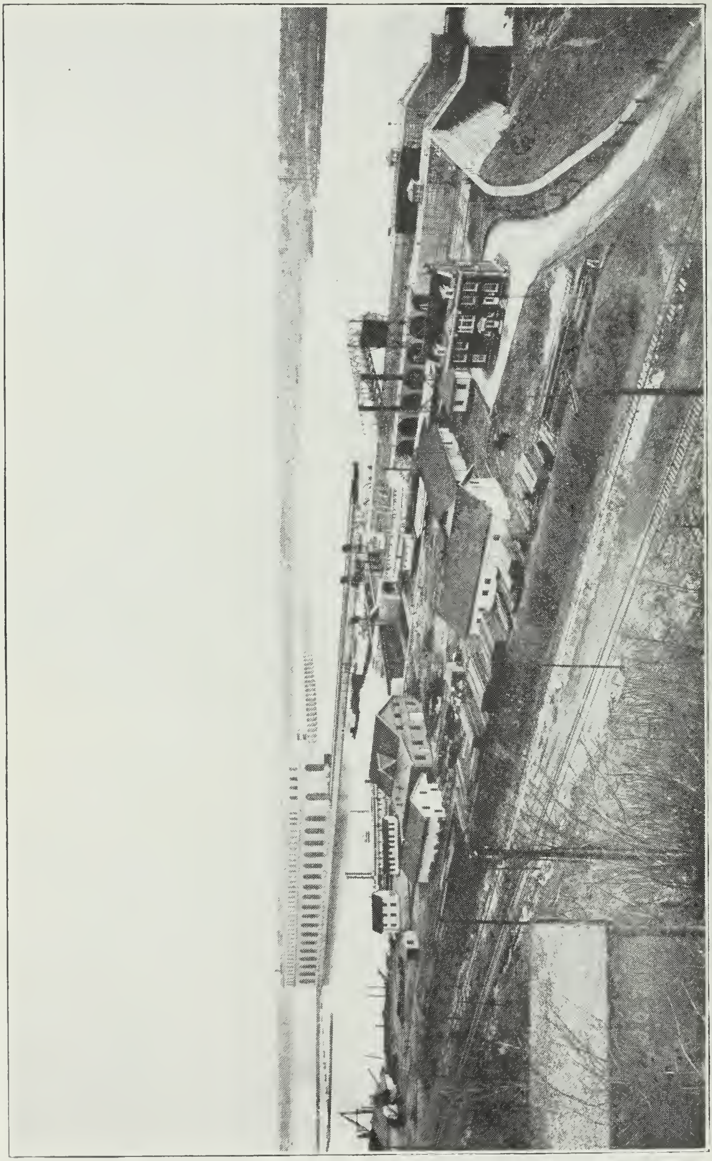
watts. It was built in 1904-1907. However, Illinois gets some of its electrical energy from the interesting and important hydroelectric development on the Mississippi River, between Keokuk, Iowa, and Hamilton, Ill., which has a rated capacity of about 135,000 kilowatts. The building of this plant was begun in 1911 and completed in 1913.

Heavy railroading is done by electric power in many places in the United States, particularly in large city terminals and in tunnels. Perhaps the most interesting example of trunk-line operation by electric locomotives is that of 650 miles of the main line of the Chicago, Milwaukee and St. Paul Railway in Montana, Idaho and Washington, crossing four mountain ranges, including the Continental Divide of the Rockies. Here waterpower, much of it from the Great Falls of the Missouri River, is changed into electric power and delivered to the railroad from a number of substations scattered along the route. The electric locomotives employed for this particular job of Electricity-at-Work are rated at 3,440 horsepower, weigh 284 tons and are 112 feet long. Each one takes the place of four ordinary steam locomotives. In crossing the Rocky Mountains this railroad reaches an altitude of 6,322 feet.

One of the more recent applications of electricity is in the propulsion of great ships. Following the example of the collier *Jupiter*, the new U. S. S. *New Mexico*, a first-class battleship 600 feet long and of 32,000 tons displacement, is electrically propelled. It is announced that the U. S. S. *California* and other capital ships of the United States Navy will also be driven by electric motors. No doubt electric drive will also be employed on merchant ships, owing to its economy and convenience.

Thirty-five Billion Kilowatt-Hours

Statistics are apt to be tiresome; but how can we show without them, in compact form, what our friend Electricity-at-Work has done? The figures are indeed imposing. It may be estimated that the total capitalization in 1918 of all the industries of the United States that may be called electrical was $14,000,000,000, and that the total income of these industries for that year was

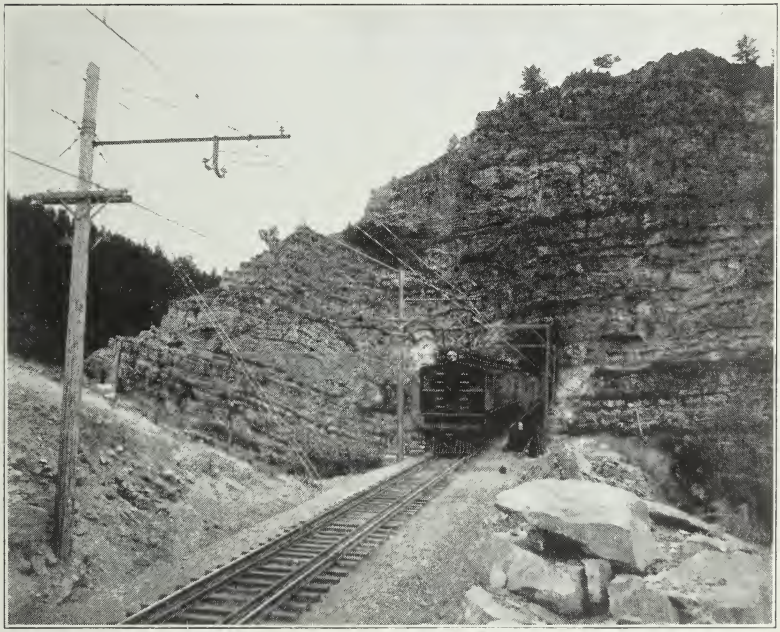


A General View of the Hydro-Electric Development "Harnessing" the Mississippi River at Keokuk

The locks for navigation are shown in the foreground.

$3,000,000,000. This, however, includes not only the electric-light-and-power central stations and electrical manufacturing, but also electric railways of various kinds, the telephone and the telegraph and other miscellaneous applications.

Concerning the electricity-supply utility itself, more exact figures are at hand for the year 1917. The United States Census Reports show that for that year electric-light-and-power stations



Electric Locomotive Drawing Passenger Train Emerging From Eagle Nest Tunnel in Rocky Mountains.

of the United States generated more than 25,000,000,000 kilowatt-hours* of electrical energy, producing an income of more than $500,000,000, and giving employment to more than 100,000 persons. Detailed figures are given in the table on next page, showing the remarkable increases since 1907. For instance, the

*Careful estimates put the corresponding figure for 1919 at about 35,000,000,000 kilowatt-hours.

rating of stationary electric motors served from central stations increased over 450 per cent in the ten years from 1907 to 1917.

Electric Light and Power Stations in the United States

	1917	1912	1907
Number of establishments..	6,541	5,221	4,714
Commercial	4,224	3,659	3,462
Municipal	2,317	1,562	1,252
Income	$526,886,408	$302,273,398	$175,642,338
Electric service............	$502,100,346	$287,138,657	$169,614,691
All other	$ 24,786,062	$ 15,134,741	$ 6,027,647
Total expenses, including salaries and wages	$427,136,049	$234,577,277	$134,196,911
Number of persons employed.	105,546	79,335	47,632
Salaries and wages.......	$ 95,239,954	$ 61,161,941	$ 35,420,324
Total horsepower............	12,857,998	7,530,044	4,098,188
Steam engines:			
Number	7,464	7,847	8,054
Horsepower	8,389,389	4,949,778	2,693,273
Internal combustion engines:			
Number	2,946	1,116	463
Horsepower	217,186	111,035	55,828
Water wheels:			
Number	3,357	2,939	2,481
Horsepower	4,251,423	2,469,231	1,349,087
Kilowatt capacity of dynamos	9,001,872	5,165,439	2,709,225
Output of stations, kilowatt-hours	25,438,611,417	11,569,109,885	5,862,276,737
Stationary motors served:			
Number	554,817	435,473	167,184
Horsepower	9,216,323	4,130,619	1,649,026
Number of street lamps:			
Arc	256,838	348,643	....
Incandescent, etc..........	1,389,382	681,957	....

The capitalization of the electricity-supply utility of the United States in 1917 was probably $3,000,000,000 or more. It takes from four to seven years for the electric-service company to "turn over" its capital. Thus for every $1.00 of income the utility has from $4.00 to $7.00 invested, so that, if money costs the utility 7 per cent, the annual interest charge on every dollar of income is from 28 cents to 49 cents. In the electrical manufacturing industry, the figures for 1918 (see page 31) show a turnover of capital in less than eight months, or three times in two years—a decided contrast.

Electrical Manufactures and Exports

As to the production of electrical machinery, apparatus and supplies, no census figures are available later than 1914. The value of these products for that year was placed at $359,412,676. Some of the principal items of this total were:

Insulated wires and cables	$69,505,573
Motors	44,176,235
Dynamos	23,233,437
Telephone apparatus	22,815,640
Magneto-ignition apparatus, sparks, coils, etc	22,260,847
Incandescent lamps	17,350,385
Transformers	13,120,065
Storage batteries	10,615,150
Electric measuring instruments	8,786,506
Primary batteries	8,719,164
Electric heating apparatus	4,034,436
Electric locomotives	3,720,914
Telegraph apparatus	2,248,375

For the year 1918 the value of electrical machinery, apparatus and supplies produced in the United States was probably not far from $900,000,000, for the three principal electrical manufacturing companies in the United States alone reported sales, for that year, of $522,421,220. This was on a capitalization of $320,015,-135. Aside from the three largest, there are probably over a thousand other electrical manufacturing establishments in the country, some of which are of large size. Expressed in tabular form, the capitalization and sales of the three leading electrical manufacturing companies of the United States for 1918 were as follows:

	Capitalization	Sales
General Electric Company	$152,921,800	$216,815,277
Westinghouse Electric & Manufacturing Company (year ended March 31, 1919)	96,127,650	160,379,943
Western Electric Company, Inc.	70,965,685	145,226,000
	$320,015,135	$522,421,220

It is to be remarked in relation to the sales of electrical manufacturing concerns tabulated above that they related to a year of war, when the demand was very heavy and prices were very

high. In 1914 New York was the first electrical manufacturing state in value of products, Illinois being second, Pennsylvania third, Massachusetts fourth, New Jersey fifth and Ohio sixth.

About 40 per cent of the electrical energy produced in the United States comes from waterpower, the remaining 60 per cent being generated in stations using coal, oil or other fuel. In states like Illinois and New York about one-third of all the primary power requirements are supplied from electric central stations.

Uncle Sam's Electricity-at-Work sends his handiwork all over the world. For the year ended December 31, 1919, the value of electrical exports from the United States was $89,089,711. This is the largest valuation of electrical exports from the United States ever recorded for one year. The corresponding figure for 1918 was $59,982,526.

The Old Order Changeth

While the material progress of this servant of mankind has been truly marvelous, the conception of the manner in which electricity should be produced and applied to public use has undergone very great changes. When electric central stations were first established, no one could foresee the dominating part which electricity was destined to play in modern life. Electric-light companies were started purely as private ventures, often as the result of the urging of manufacturers of electrical machinery, and the business was exploited like any private business. At first, too, the central stations were purely local affairs. There was a great "boom" in electrical affairs in the late eighties and early nineties. Next came the business depression of 1893 to 1896. Thereafter the managers of electric-service enterprises began to study their business with more care, with deeper insight and with a keener appreciation of its economic position in the community.

It was discovered that the old system of flat rates for electric service was unjust, both to the community as a whole and to the producer. Rates were, therefore, gradually adjusted on the basis of the characteristics of the *demand* made on the central-station

company. The percentage of time that electricity is used in proportion to the time when it is available for use is called the "load factor" of the utility, and a diligent effort was made to improve this load factor. In making rates it was seen not to be just that a man who uses the central-station investment only, say, 100 hours a year, should be able to buy the product at the same price per unit as a man who uses the investment, say, 3,000 hours a year, when the amounts of money invested to take care of the two customers are precisely the same. Rates should be adjusted so as to pay the operating expenses required for good service, plus a fair return on the money invested, plus a reasonable allowance to meet depreciation. So far as it can be arranged in practice, every customer should pay a rate proportionate to the cost of the service furnished to him, remembering that electric service from central stations is more of the nature of a service than of a commodity.

The Laborer Is Worthy of His Hire

In studying the achievements of Electricity-at-Work one important thing to remember is that the rates for electrical energy, going back for a term of years, have in most localities materially decreased, unless, under the stress of war conditions, increases have been necessary in the last three or four years. But, on the whole, these prices have decreased, while it is equally true that the rates for necessities like food, clothing, fuel and taxes have increased from 75 to 250 per cent or more. This contrast is illustrated by a diagram given on page 35. This is accounted for, in spite of the fact that the labor and materials used in the production of electrical energy have very materially increased in price, by the fact that, with the advance in the art, great economies have been effected by the use of large generating units, improved incandescent lamps, and in other ways. Furthermore, the almost universal use of electricity nowadays for all sorts of purposes enables the machinery and other equipment to be used for a greater proportion of the twenty-four hours. This reduces the cost. Conservative financing has also played its part.

In the eighties central-station rates were equivalent to about 25 cents a kilowatt-hour. In 1898 the average income of large companies was in the neighborhood of seven cents a kilowatt-hour, while in 1919 the average income of the Commonwealth Edison Company of Chicago was about two cents a kilowatt-hour. Many factors enter into the making of equitable rates, and the cost of producing and distributing electricity varies to a very considerable extent in different communities.

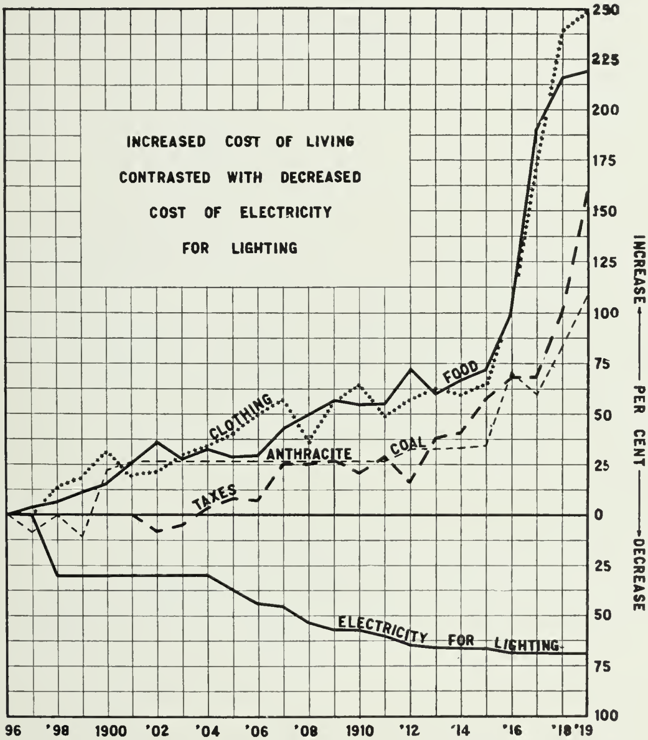
How This Servant Does His Best Work

Gradually it was discovered also that the hap-hazard hit-or-miss plan of allowing two or a dozen or half a hundred central-station organizations in a given community was all wrong. It was found that the cheapest and most efficient way to produce and distribute electrical energy was by operating the utility as a monopoly over as large a territory as could be economically served from one organization. The word "monopoly," as used here, does not have the offensive meaning of that word at common law, but indicates an exclusive privilege, the company being subjected to such reasonable regulation that it is shorn of all the evils of a monopoly. At first the electric-service utilities were regulated by municipal authorities, by politics, by competition, or by threats of competition, but in late years the plan of regulation by state public-utility commissions has been adopted largely. Out of the forty-eight states in the Union forty have public-utility commissions with authority over electric-light-and-power companies.

Central-station managers have come to look upon themselves as semi-public officials; they aim to conduct their affairs with the community so as to secure the advantage of a reputation for absolutely fair and impartial dealing. No longer is the electricity-supply enterprise regarded as a private venture; it is now, indeed, a public utility. In a public-utility enterprise no man is so highly placed that he can afford to be arrogant, nor is any man so lowly that he need be servile.

To effect greater economy, and often to improve the quality of the service, the generation of electrical energy in small places is

often abandoned, such towns and the intermediate territory between them being served from a network of electrical transmission and distribution lines, the electricity being generated at large stations at economical points of production and transmitted to local substations and distributing systems.



Other Prices Go Up; Electric Lighting Goes Down
The figures are for Chicago.

During the period of this transformation from local plants to large systems a few service interruptions on the "high lines," as the transmission lines are sometimes called, have been reported. It is no doubt true that at the present time, at the close of the Great War and during the troubled era of reconstruction, the companies that direct Electricity-at-Work have not been able

to secure capital adequate to the building of transmission lines of ample capacity, having sufficient reserve to protect against interruptions. But the ultimate advantage to the consumer of being a part of these large interconnected systems is so great that any slight inconvenience of the development period may be borne with patience.

Paralleling of investments in the shape of generating stations and distributing systems simply adds to the cost of the product which the community purchases. Therefore, a regulated monopoly, whether such monopoly is privately operated or publicly operated, is more in accordance with scientific methods than regulation by competition. The economic tendency toward the combination and centralization of electricity supply has been very marked in the United States during the last ten or fifteen years.

Fair Play for the Burden Bearer

The duties of Electricity-at-Work are now tremendously important. In considering the public relations of public-utility companies it may be well to remember that management *for* the people is not necessarily management *by* the people. Obviously the people cannot, of themselves, perform the highly technical task of operating public utilities. They must employ experts for this purpose. And, in this country and at this time, the best way to secure the best service of the best experts—to give the public the best service at the lowest rates consistent with the best service—is to permit private enterprise a suitable financial reward to serve as an incentive, so that the character of brains so greatly needed for this complex undertaking shall be attracted to the work.

Theodore Roosevelt is reported to have said: "I do not believe in government ownership of anything which can with propriety be left in private hands." Another great man, a fair-minded man, who has given thought to this subject, is Thomas A. Edison. Referring to old contracts for five-cent fares on street railways, Mr. Edison said quite recently: "The municipalities can exact their pound of flesh if they so desire, with the ultimate bankruptcy of these organzations. But the spirit that is now

abroad in the world is against this. We are all trying to play fair. If suffer we must, we must all suffer alike. If prosperity comes, all should participate in a like manner.''

Municipal operation has the theoretical advantage that capital can be borrowed more cheaply and that it is not necessary to make a profit. However, opposed to these, are the practical advantages of careful management, continuity of management and private initiative. Mr. E. N. Hurley, who served during the

A Modern Electric Substation in a Small Illinois Town

recent war as chairman of the United States Shipping Board, when asked what had impressed him most in carrying out his great task, said: ''The efficiency of private ownership and operation, as compared with public ownership and operation.'' Mr. Hurley declared that the whole proposition of government ownership is fine in theory, but that in practice the push of individual energy is missing.

In the larger plans being worked out for the distribution of cheap electricity over the country through interconnected net-

works, the small local plant, including the small municipal plant, seems to be out of place. Large systems covering wide areas can be more economically operated, thus serving the people best in the long run. This is a very important aspect of the subject, and all citizens with the good of the country at heart should have knowledge of the importance of power production and distribution in the United States, so that the pressure of public opinion will back up those in authority, who should have vision and imagination in understanding the great importance of Electricity-at-Work.

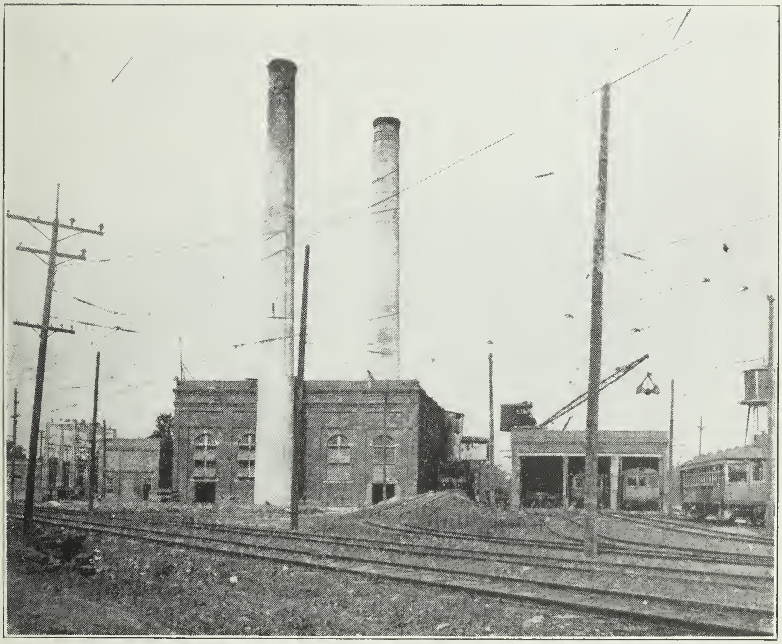
Really the matter is simply one of common honesty in giving the electrical utility a fair and just return for work faithfully performed.

Today and Tomorrow

Fortunately the electrical requirements of Smith, Jones and Robinson—or of the light-and-power, street-railway, industrial, mining, farming and transportation interests of a state or a part of a state—do not exactly coincide. Thus the centralized electricity-supply system can utilize this diversity of demand to better advantage than a number of power-producing systems. It has been estimated that if the primary power requirements of the United States were massed in a number of economic power areas, each supplied with its own interlinked system of generating, transmitting and distributing electrical energy, the saving in fuel alone, compared with present conditions, would be probably not less than $1,000,000,000 a year.

What has been accomplished thus far in electrical development, in directing Electricity-at-Work, has been due to private initiative. Apparently the future demands that will be made on this faithful servant are almost without limit. Electric power is bound to be used to a much greater extent in agricultural operations, in metallurgy, in operating the trains of trunk-line railroads and in the home. In states like New York and Illinois perhaps one-third of primary power requirements are supplied from electric central stations. The time will come, no doubt, when this proportion will be nearly 100 per cent. Waterpowers

should be developed to the greatest extent, but, according to Dr. C. P. Steinmetz, the hope that if coal should fail we may use the waterpowers of the country as a compensatory source of energy is a dream, because if all the possible waterpowers of the country were developed the resulting energy would hardly supply the present demand. Probably the possibility of the exhaustion



Electric Generating Station in Southern Illinois
Much of the output of this plant goes to coal mines.

of the coal supply of the world is so remote that the study of such sources of power as atomic energy, solar radiation, the heat of the earth, winds and tides, is not of immediate pressing importance. Whatever the future may hold for us in the manner of sources of power, it is at present certain that Electricity-at-Work is a most economical and convenient servant for applying energy to conditions of actual work.

The cost of power is very closely related to the welfare of the human race. It is probable that the future will see networks of electrical distribution systems covering all the populous parts of the United States, with large electrical generating stations feeding into this network at points where electrical energy can be produced most cheaply. These stations may be driven by steam engines, waterwheels or oil or gas engines. Many of the material problems of modern society relating to the conditions of life and labor and the bringing up of children will be met more satisfactorily when cheap electric power is thus spread over the land, throughout rural communities, so that it may be "on tap" whereever other conditions are favorable for industrial operations, thus relieving much of the congestion in crowded centers of population. Electricity-at-Work is looking ahead to his great task of today and tomorrow—that of bringing cheap power and the comforts of modern civilization to every man's door.